Journal of Animal and Veterinary Advances 9 (1): 70-74, 2010
ISSN: 1680-5593

Growth Performance and Blood Parameters as Influenced by Different Levels of Dietary Arginine in Broiler Chickens

[1]M. Emadi, [2]K. Kaveh, [3]M.H. Bejo, [2]A. Ideris, [4]F. Jahanshiri, [5]M. Ivan and [1]R.A. Alimon
[1]Department of Animal Science, Faculty of Agriculture,
Putra Malaysia University, 43400, Serdang, Selangor, Malaysia
[2]Department of Clinical Studies,
[3]Department of Pathology and Microbiology, Faculty of Veterinary Medicine,
Putra Malaysia University, 43400, Serdang, Selangor, Malaysia
[4]Department of Microbiology, Faculty of Biotechnology,
Putra Malaysia University, 43400, Serdang, Selangor, Malaysia
[5]Institute of Tropical Agriculture, Putra Malaysia University, 43400, Serdang, Selangor, Malaysia

Abstract: An experiment was conducted to determine effects of dietary Arginine (ARG) on growth performance and blood serum parameters in broiler chickens. A corn-soybean meal based diet containing different levels of ARG (0, 0.67, 1.37, 2.07 and 2.77) for the starter (0, 0.53, 1.1, 1.68 and 2.25) for the grower and (0, 0.52, 1.04, 1.56 and 2.08) for the finisher was used. In a completely randomized design with five treatments of five replicates each and 10 chickens per replicate, 250 Cobb 500 male broiler chickens from 0-49 days of age were used. Growth performance (body weight gain, feed intake and feed: gain ratio) and blood serum (albumin, total protein, glucose, cholesterol, triglyceride, urea, uric acid, aspartate amino-transferase, alanine amino-transferase, alkalin phosphatase, lactic dehydrogenase and creatine kinase) parameters were measured at 27 and 49 days of age. Increase of dietary ARG increased ($p<0.05$) body weight gain, feed intake, albumin, creatine kinase, glucose, urea and uric acid and decreased ($p>0.05$) aspartate amino-transferase and cholesterol. It was concluded that dietary ARG might have positive effects on health status of the broiler chickens.

Key words: Arginine, growth performance, blood parameter, broiler chicken, cholesterol, amino-transferase

INTRODUCTION

Uricotelic species (i.e., birds) cannot synthesize Arginine because they have an incomplete urea cycle. Past research has clearly demonstrated the importance of providing chickens adequate dietary ARG to support growth responses (Cuca and Jensen, 1990). Arginine, like most amino acids, is traditionally noted for its role in protein synthesis. Many studies recognized the importance of ARG on growth, immunity (Kidd *et al*., 2001), wound healing (Evoy *et al*., 1998) and greater muscle mass and rapid healing from injury (Cooper and Kenneth, 1996). Arginine is a potent scavetagogue for growth hormone, insulin and insulin-like growth factor-1. Above all, insulin and growth hormone regulate the metabolism of glucose and amino acids in major tissues including skeletal muscle, adipose tissues liver and heart (Meijer and Dubbelhis, 2004). Arginine is famous for its role in enhancing the ovulation process of the hens through boosted release of Luterinzing Hormone (LH), which is necessary for ovulation chickens (Najib and Basiouni, 2004). The plasma concentration of ARG decreased significantly in relation to protein malnutrition, fasting, trauma, burn injury, inflammation and liver transplantation. Under these conditions, ARG must be offered in the diet to support both the nitrogen balance and health status of animals. ARG is believed to be important for efficient muscle metabolism, owing to its role in transport, storage and elimination of nitrogen (Flynnl *et al*., 2002). Gonzalez-Esuerra and Leeson (2006) observed improved performance in birds fed with high levels of ARG, when acutely and chronically heat stressed. Najib and Basiouni (2004) improved status of egg production of the laying hens by increasing dietary ARG. Under most circumstances ARG will not be limiting due to its high concentration in widely used soybean meal supplements. However, it might be of concern, when other dietary high protein supplements replace soybean meal, but a more precise requirement for dietary ARG by broilers has not been established. Therefore, the primary

Corresponding Author: A.R. Alimon, Department of Animal Science, Faculty of Agriculture, Putra Malaysia University, 43400, Serdang, Selangor, Malaysia

objective of the current study was to determine the dietary ARG concentration required for the maximum performance of broilers utilizing the Body Weight Gain (BWG) and Feed Intake (FI) as the performance parameters. The effects of ARG on several blood parameters were also measured.

MATERIALS AND METHODS

Five different dietary levels (A-E) of ARG for three age group periods (starter, grower and finisher) of broiler chickens were used. There were (Table 1) five levels of ARG for the Starter (S) 0-21 days of age (S-A, 0-control; S-B, 0.67; S-C, 1.37; S-D, 2.07 and S-E 2.77), five levels for the Grower (G) 21-42 days of age (G-A, 0-control; G-B, 0.53; G-C, 1.1; G-D, 1.68 and G-E, 2.25) and five for the Finisher (F) 42-49 days of age (F-A, 0-control; F-B, 0.52; F-C, 1.04; F-D, 1.56 and F-E, 2.08). All diets met the National Research Council (1994) recommendations for broilers. One-day-old Cobb 500 male broiler chickens (250) were utilized in the experiment consisting of 5 treatments with 5 replicates and 10 chickens per replicate each. Birds were housed randomly in pen, so that initially each bird occupied approximately 0.11 m^2 of floor space. The pens were floor pens with wood litter. Birds were maintained under continuous light and the environmental temperature in the barn was initially set at 31°C and was gradually reduced to 20°C by week 7. Feed and water were provided *ad-libitum* throughout the experiment. Chickens were vaccinated for Marek`s, infectious bursal and infectious bronchitis diseases at the hatchery and then at 7 and 14 days of age for Newcastle disease. Body weight gain and FI were recorded weekly and adjusted for the three periods (starter, grower and finisher). At 27 and 49 days of age, two chickens was randomly selected from each replicate in each treatment and blood samples were collected from the wing vein by Terumo Syringe with needle (0.7×32 mm). Blood samples (ten samples for each treatment) were allowed to cloth and then centrifuged and serum was separated and stored at -20 EC until analyzed for serum parameters (albumin, total protein, glucose, cholesterol, triglyceride, urea, uric acid, Aspartate Amino-Transferase (AST), Alanine Amino-Transferase (ALT), Alkalin Phosphatase (ALP), Lactic Dehydrogenase (LDH) and Creatine Kinase (CK)) using automatic analyzer according to the recommendation of the manufacturer (Aravind *et al*., 2003).

A completely randomized experimental design was used. All data were statistically analyzed using the General Linear Models (GLM) procedure of SAS software (SAS, 1996) for analysis of variance. Duncan (1955) multiple range test was used to determine differences among treatment means. Means were considered different at $p<0.05$.

Table 1: Composition of experimental diets of broiler chickens during 0-49 days of age

	Starter (S)					Grower (G)					Finisher (F)				
Ingredients	S-A	S-B	S-C	S-D	S-E	G-A	G-B	G-C	G-D	G-E	F-A	F-B	F-C	F-D	F-E
Corn grain	54.4	54.4	54.4	54.4	54.4	67.9	67.9	67.9	67.9	67.9	71.1	71.1	71.1	71.1	71.1
Soybean meal	35.3	35.3	35.3	35.3	35.3	22.6	22.6	22.6	22.6	22.6	20.03	20.03	20.03	20.03	20.03
Fish meal	1.09	1.09	1.09	1.09	1.09	4.3	4.3	4.3	4.3	4.3	2.5	2.5	2.5	2.5	2.5
Dicalcium phosphate	1.35	1.35	1.35	1.35	1.35	0.54	0.54	0.54	0.54	0.54	0.55	0.55	0.55	0.55	0.55
Limestone	1.17	1.17	1.17	1.17	1.17	1.19	1.19	1.19	1.19	1.19	1.12	1.12	1.12	1.12	1.12
Vitamin - mineral mix[1]	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Vegetable oil	2.8	2.8	2.8	2.8	2.8	-	-	-	-	-	-	-	-	-	-
Salt	0.4	0.4	0.4	0.4	0.4	0.24	0.24	0.24	0.24	0.24	0.2	0.2	0.2	0.2	0.2
DL-methionine	0.14	0.14	0.14	0.14	0.14	-	-	-	-	-	-	-	-	-	-
Arginine	0	0.67	1.37	2.07	2.77	0	0.53	1.1	1.68	2.25	0	0.52	1.04	1.56	2.08
Wheat bran	2.8	2.13	1.43	0.73	0.003	2.6	2.07	1.5	0.92	0.35	3.99	3.47	2.95	2.43	1.91
Calculated analysis															
ME[2] (kcal kg^{-1})	2900	2900	2900	2900	2900	2900	2900	2900	2900	2900	2900	2900	2900	2900	2900
Crude protein (%)	20.8	20.8	20.8	20.8	20.8	18.2	18.2	18.2	18.2	18.2	16.3	16.3	16.3	16.3	16.3
Crude fiber (%)	3.70	3.70	3.70	3.70	3.70	3.20	3.20	3.20	3.20	3.20	3.05	3.05	3.05	3.05	3.05
Linoleic (%)	2.2	2.2	2.2	2.2	2.2	1.6	1.6	1.6	1.6	1.6	1.7	1.7	1.7	1.7	1.7
Ca (%)	0.91	0.91	0.91	0.91	0.91	0.82	0.82	0.82	0.82	0.82	0.72	0.72	0.72	0.72	0.72
Available P (%)	0.41	0.41	0.41	0.41	0.41	0.32	0.32	0.32	0.32	0.32	0.27	0.27	0.27	0.27	0.27
Na (%)	0.18	0.18	0.18	0.18	0.18	0.14	0.14	0.14	0.14	0.14	0.11	0.11	0.11	0.11	0.11
Arginin (%)	1.34	2.01	2.68	3.35	4.02	1.10	1.65	2.20	2.75	3.30	1.00	1.50	2.00	2.50	3.00
Lysine (%)	1.15	1.15	1.15	1.15	1.15	1.00	1.00	1.00	1.00	1.00	0.85	0.85	0.85	0.85	0.85
Methionine + Cystine (%)	0.82	0.82	0.82	0.82	0.82	0.65	0.65	0.65	0.65	0.65	0.58	0.58	0.58	0.58	0.58
Tryptophan (%)	0.30	0.30	0.30	0.30	0.30	0.24	0.24	0.24	0.24	0.24	0.21	0.21	0.21	0.21	0.21

[1]Supplied/kilogram of diet: vitamin A, 10000 IU; vitamin D_3, 9790 IU; vitamin E, 121 IU; B_{12}, 20 μg; riboflavin, 4.4 mg; calcium pantothenate, 40 mg; niacin, 22 mg; choline, 840 mg; biotin, 30 μg; thiamine, 4 mg; zinc sulphate, 60 mg; manganese oxide, 60 mg. [2]Metabolizable energy

RESULTS

Compared to control, in all periods the values of FI, BWG and Feed Gain Ratio (FCR) have gradually increased ($p<0.001$) due to increased level of dietary ARG (Table 2). There was no abnormal behavior observed in birds receiving different levels of supplementation and FI and BWG were enhanced linearly with increased dietary ARG. This linear enhancement was continuous up to group D, but in group E a negative effect ($p<0.05$) was observed. However, compared to control dietary ARG increased ($p<0.05$) FCR in each treatment; the highest being in treatment C. The highest FI and BWG were in treatment D.

The effects of different levels of ARG on blood serum parameters in broiler chickens are summarized in Table 3-5. Arginine supplementation of control diets significantly increased the serum concentration of glucose, albumin, CK and uric acid at 27 and 49 days of age. Dietary ARG had no affect ($p>0.05$) on total triglyceride, total protein, ALT, ALP and LDH at 27 and 49 days of age. The use of ARG at 27 and 49 days of age decreased ($p<0.05$) cholesterol. At 27 days of age dietary ARG did not affect ($p>0.05$) urea, but increased ($p<0.05$) urea in chickens at 49 days of age. At 27 days of age dietary ARG decreased ($p<0.05$) AST, but had no effect ($p>0.05$) at 49 days. For glucose and albumin, the best results were achieved on 27 and 49 days of age in groups D and E. In case of cholesterol, the best result at 27 days of age were in group D and in 49 days of age it was in groups D and E. Creatine kinase, urea and uric acid were increased linearly with increased dietary ARG. Dietary ARG had no effect ($p>0.05$) on serum ALT, ALP, LDH, triglycerides and total protein, however, it could improve this parameters.

Table 2: Effects of dietary arginine on Feed Intake (FI), Body Weight Gain (BWG) and Feed Conversion Ratio (FCR) of broiler chickens from 0-49 days of age

	FI (g, days)				BWG (g, days)				FCR (days)			
Treatments	0-21	21-42	42-49	0-49	0-21	21-42	42-49	0-49	0-21	21-42	42-49	0-49
A	865^{a}	2152^{a}	1209^{a}	4057^{a}	542^{a}	861^{a}	578^{a}	1902^{a}	1.60	2.52^{a}	2.12^{b}	2.15^{a}
B	994^{b}	2439^{b}	1511^{b}	4974^{b}	625^{b}	934^{b}	662^{b}	2143^{b}	1.61	2.63^{a}	2.30^{a}	2.34^{b}
C	1118^{c}	3014^{c}	1685^{c}	5885^{c}	697^{c}	1037^{c}	729^{c}	2367^{c}	1.61	3.23^{b}	2.34^{a}	2.72^{c}
D	1303^{e}	3241^{e}	1976^{e}	6503^{e}	802^{e}	1144^{e}	852^{e}	2623^{e}	1.63	2.84^{c}	2.39^{a}	2.51^{d}
E	1197^{d}	3109^{d}	1831^{d}	6265^{d}	746^{d}	1087^{d}	777^{d}	2515^{d}	1.62	2.88^{c}	2.38^{a}	2.53^{d}
SE	9	22	13	42	9	11	15	27	0.02	0.03	0.04	0.04
P	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.92	0.001	0.001	0.001
R^2	0.72	0.77	0.77	0.81	0.46	0.42	0.20	0.39	0.00	0.10	0.01	0.02

Table 3: Effects of dietary arginine on the serum concentration of Glucose (GLU), Total Protein (TP), Albumin (ALB) and Creatine Kinase (CK) in broiler chickens at different days of age

	GLU (mg dL^{-1}, days)		TP(g dL^{-1}, days)		ALB (g dL^{-1}, days)		CK (U L^{-1}, days)	
Treatments	27	49	27	49	27	49	27	49
A	127^{b}	214^{a}	2.24	2.31	0.99^{b}	1.05^{b}	1323^{b}	1470^{b}
B	159^{ab}	222^{a}	2.17	2.63	0.94^{b}	1.50^{ab}	1304^{b}	1480^{b}
C	146^{ab}	214^{a}	2.38	2.63	1.37^{b}	1.78^{ab}	1341^{b}	1387^{b}
D	176^{a}	227^{a}	2.43	2.87	2.27^{a}	1.98^{a}	1385^{ab}	1521^{a}
E	175^{a}	256^{b}	2.38	2.67	2.62^{a}	2.09^{a}	1426^{a}	1456^{ab}
SE	14	5	0.11	0.32	0.17	0.21	24	16
P	0.05	0.001	0.54	0.70	0.001	0.04	0.03	0.04
R^2	0.08	0.62	0.02	0.02	0.64	0.36	0.19	0.39

Table 4: Effects of dietary arginine on the serum concentration (mg dL^{-1}) of Triglyceride (TRIG), Cholesterol (CHOL), Urea (URE) and Uric Acid (UA) in broiler chickens at different days of age

	TRIG (days)		CHOL (days)		URE (days)		UA (days)	
Treatments	27	49	27	49	27	49	27	49
A	125.6	125.3	164^{b}	173^{a}	2.5	2.9^{c}	4.05^{c}	4.71^{b}
B	126.2	125.3	133^{ab}	163^{ab}	2.4	3.3^{b}	4.20^{c}	5.53^{a}
C	124.8	124.3	160^{b}	160^{ab}	2.5	3.6^{ab}	4.45^{b}	5.66^{a}
D	125.0	124.3	118^{ab}	147^{b}	2.5	3.8^{a}	4.50^{ab}	5.70^{a}
E	125.8	124.5	132^{a}	141^{b}	2.5	3.8^{a}	4.72^{a}	6.10^{a}
SE	0.9	1.2	16	9	1.3	1.3	0.06	0.34
P	0.13	0.93	0.05	0.04	0.88	0.001	0.001	0.01
R^2	0.08	0.003	0.14	0.34	0.002	0.57	0.62	0.49

Means in each columns with different superscripts are significantly different ($p<0.05$)

Table 5: Effects of dietary arginine on the activity (U L^{-1}) of serum alanine Amino-Transferase (ALT), Alkalin Phosphatase (ALP), Aspartate Amino-Transferase (AST) and Lactic Dehydrogenase (LDH) in broiler chickens at different days of age

	ALT (days)		ALP (days)		AST (days)		LDH (days)	
Treatments	27	49	27	49	27	49	27	49
A	39.0	46.0	389	427	267^a	335	1268	1325
B	37.0	45.3	389	449	275^a	332	1266	1336
C	35.0	42.3	386	431	192^b	300	1250	1323
D	36.0	43.0	383	450	218^b	300	1262	1341
E	45.4	44.3	387	433	213^b	322	1261	1311
SE	0.1	1.30	26	13	12	17	16	24
P	0.68	0.36	0.60	0.59	0.001	0.36	0.09	0.87
R^2	0.01	0.12	0.01	0.06	0.38	0.09	0.09	0.01

Means within columns with different superscripts are significantly different ($p<0.05$)

DISCUSSION

As expected, dietary ARG increased FI and BWG. This is in agreement with Abdukalykova and Ruiz-Feria (2006). Corzo and Kidd (2003) showed that high level of dietary ARG had no effect on broilers during the total growth period, except for the first 3 weeks of age. Association of available ARG with microbial challenges occurring at younger ages has been shown to have affected growth performance and health status of the bird (Kidd *et al*., 2001). Similar ARG observations were reported by Chamruspollert *et al*. (2001), where a higher requirement of ARG was needed for feed conversion than that for BWG. During the present study ARG supplementation had no positive effect on FCR. Recent data obtained in chickens showed that dietary ARG had positive influences on the growth performance of birds inoculated with infectious bronchitis virus (Lee *et al*., 2002) and Gonzalez-Esuerra and Lesson (2006) showed in a heat-stress experiment that high levels of dietary ARG improve BWG. Brake *et al*. (1998) in a similar experiment observed improved growth performance in birds fed ARG: LYS ratio at 1.37 vs. those fed ratios of 1.10 suggested by National Research Council (1994). High levels of dietary ARG intake increased FI and egg production without any significant effect on egg weight (Basiouni *et al*., 2006).

Increasing dietary ARG in the present study resulted in improvement in blood plasma parameters. Deficiency of ARG impaired insulin production, glucose production and liver lipid metabolism (Balch *et al*., 1997), because it is involved in the production of variety of enzymes and hormones. Arginin facilitated the release of Growth Hormone (GH) and stimulated the pancreas for insulin production (Balch *et al*., 1997). It also increased the levels of glucose and GH (Braverman, 1997). An increase in blood glucose may be an indication of metabolic adaptation for gluconeogenesis in broilers experiencing threatening conditions in maintaining amino acid homeostasis (Corzo *et al*., 2005).

Broilers with higher body weight were observed to have a higher concentration of blood plasma total protein, when compared with the lighter broilers, possibly associated with higher demand for lean tissue maintenance and turn over (Corzo *et al*., 2005). Feeding low protein and amino acid diets have been shown to be associatiated with decreased total serum protein and serum albumin in chickens. Dietary ARG can contribute to a hormonal environment that produces increased protein synthesis and muscle growth (Leveilla *et al*., 1960).

As a cholesterol fighter, a high ratio of ARG: LYS is recommended (Braverman, 1997). Arginine aids in liver detoxification by neutralizing ammonia and may be beneficial in the treatment of liver disorders such as liver injury, hepatic cirrhosis and fatty liver degeneration (Braverman, 1997; Balch *et al*., 1997); CK is an important enzyme in such tissues (McLeish and Kenyon, 2005). Creatine, which derived from ARG, plays important roles in muscle metabolism. Arginine is also the only amino acid that provides the amidino group for synthesis of CK, a major reserve of high energy phosphate for regeneration of ATP in the muscle (Evoy *et al*., 1998). Therefore, ARG plays a significant role in protein synthesis, urea cycle metabolism, high-energy compounds synthesis, creatine, creatine phosphate, polyamine synthesis and the production of nitric oxide.

CONCLUSION

The use of ARG may improve the growth performance and health status of broiler chickens. Although, dietary ARG increased all blood parameters it did not produce any toxic effects because all blood parameters were in normal range.

REFERENCES

Aravind, K.L., V.S. Patil, G. Devegowda, B. Vmakanthas and S.P. Ganpule, 2003. Efficacy of esterified glucomannan to counteract mycotoxicosis in naturally contaminated feed on performance and serum biochemical and hematological parameters in broilers. Poult. Sci., 82: 571-576. http://ps.fass.org/cgi/reprint/82/4/571.pdf.

Abdukalykova, S. and S. Ruiz-Feria, 2006. Arginine and vitamin E improve the cellular and humoral immune response of broiler chickens. Int. J. Poult. Sci., 5: 121-127. http://www.pjbs.org/ijps/fin539.pdf.

Balch, M.D., F. James., C.N.C. Balch and A. Phyllis, 1997. Prescription for nutritional healing. 2nd Edn. Avery Publishing group, New York, pp: 35-36.

Basiouni, G., H. Najib, M.M. Zaki and A.S. Al-Ankari, 2006. Influence of extera supplementation with Arginine and lysine on overall performance, ovarian activities and humoral immune response in local Saudi hens. Int. J. Poult. Sci., 5: 441-448. http://www.pjbs.org/ijps/fin597.pdf.

Brake, J., D. Balnave and J.J. Dibner, 1998. Optimum dietary arginine: Lysine ratio for broiler chickens is altered during heat stress in association with changes in intestinal uptake and dietary sodium chloride. Br. Poult. Sci., 39: 639-647. http://www.medscape. com/medline/abstract/9925317.

Braverman, M.D., 1997. The Healing Nutrients Within New Canaan, CT: Keats Publishing, Inc, pp: 18-23.

Chamruspollert, M., G.M. Pesti, and R.I. Bakalli, 2001. The influence of labile dietary methyl donors on the arginine requirement of young broiler chicks. Poult. Sci., 81: 1142-1148. http://www.poultryscience.org/ps/paperpdfs/02/p0281142.pdf.

Cooper, M.D. and M.P.H. Kenneth, 1996. Advanced nutrition therapies. Nashville. Thomas Nelson, Inc. Publishers, pp: 87-88.

Corzo, A. and M.T. Kidd, 2003. Arginine needs for chick and growing broiler. Int. J. Poult. Sci., 2: 379-382. http://www.pjbs.org/ijps/fin125.pdf.

Corzo, A., E.T. Moran, D. Hoehler and A. Lemme, 2005. Dietary tryptophan need of broiler males from 42-56 days of age. Poult. Sci., 84: 226-231. http://www.poultryscience.org/ps/abs/05/p0520226.htm.

Cuca, M. and L.S. Jensen, 1990. Arginine requirement of starting broiler chicks. Poult. Sci., 69: 1377-1382. http://www.ncbi.nlm.nih.gov/pubmed/2235851?dopt=Abstract.

Duncan, D.B., 1955. Multiple range and F-tests. Biometrics, 11: 1-42.

Evoy, D., M.D. Lieberman, T.J. Fahey and J.M. Daly, 1998. Immunonutrition: The role of arginine. J. Nutr., 14: 611-617. https://profreg.medscape.com/px/getlogin.do?urlCache=aHR0cDovL3d3dy5tZWRzY2FwZS5jb20vdmlld2FydGljbGUvNDY 4Nzg4XzU.

Flynnl, N.E., C.J. Meininger, T.E. Haynes and G. Wu, 2002. The metabolic basis of arginine nutrition and pharmacotherapy. Biomed. Pharmacother, 56: 427-438. http://www.ncbi.nlm.nih.gov/pubmed/12481979?dopt=Abstract.

Gonzalez-Esuerra, R. and S. Lesson, 2006. Effect of arginine: Lysine ratios and source of methionine on growth and body protein accretion in acutely and chronically heat-stressed broilers. Poult. Sci., 85: 1594-1602. http://www.poultryscience.org/ps/abs/06/p0691594.htm.

Kidd, M.T., E.T. Peebles, S.K. Whitmarsh, J.B. Yeatman and R.F. Wideman, 2001. Growth and immunity of broiler chicks as affected by dietary arginine. Poult. Sci., 80: 1535-1542. http://www.poultryscience.org/ps/abs/01/p01B1535.htm.

Lee, J.E., R.E. Austic., S.A. Naqi, K.A. Golemboski and R.R. Dietert, 2002. Dietary Arginine intake alters avian leukocyte population distribution during infectious bronchitis challenge. Poult. Sci., 81: 793-798. http://www.poultryscience.org/ps/abs/02/p0260793.htm.

Leveilla, G.A., A.S. Feigenbaum and H. Fisher, 1960. The effect of dietary protein, fat and cholesterol on plasma cholesterol and serum protein components of the growing chick. Arch. Biochem. Biophys., 86: 67. http://www.pubmedcentral.nih.gov/articlerender.

Mcleish, M.J. and G.L. Kenyon, 2005. Relating structure to mechanism in creatine kinase. Crit. Rev. Biochem. Mol. Biol., 40: 1-20. http://www.citeulike.org/article/145897.

Meijer, A.J. and P.F. Dubbelhis, 2004. Amino acid signaling and the integration of metabolism. Biochem. Biophys., 313: 397-403. http://www.ncbi.nlm.nih.gov/pubmed/14684175?dopt=Abstract.

Najib, H. and G. Basiouni, 2004. Determination of the nutritional requirements of the local Saudi chickens. Sci. J. King Fasial Univ., 5: 131-144. http://www.pjbs.org/ijps/fin597.pdf.

National Research Council (NRC), 1994. Nutrient Requirements of Poultry. 9th Rev. Edn. National Academy Press, Washington, DC, USA. http://sites.nationalacademies.org/NRC/index.htm.

SAS Institute, 1996. SAS User=s Guide: Statistics. Version 7.0. Cary, NC, USA.